

Challenges in Engineering and Fabrication of Combination Units with Double Side Metal Lined Intermediate Dished Heads.

Combination units are quite common in refinery, chemical, and other industrial applications. A combination unit is a pressure vessel that consists of more than one pressure chamber, operating at the same or different pressures and temperatures. The parts separating each pressure chamber are the common elements, generally an intermediate dished head. The Intermediate dished heads may be designed either for differential pressure and mean metal temperature, or to operate independently. If the operating fluids are corrosive in nature then the vessel is required to have a high alloy metal lining, hence the intermediate dished head require a high strength base material with metal lining on both sides, either by cladding or by weld overlay. Metal lining on both sides of the dished head possess many challenges in fabrication.

In this paper, the author has specifically talked about one of the possible configuration and fabrication sequence for double side metal lined intermediate head to metal lined shell joint. It also presents the common element design for combination units and weld joint design for shear based on pressure inside the chambers.

Combination units are used where the pressure chambers are required to be isolated from one another due to process reasons and one chamber is to be maintained at an elevation above other chamber. Refer figure (a).

The Combination units are the pressure vessels that are having two or more pressure chambers separated by a common element. Each pressure chamber operates at same or different pressure and temperatures. These pressure chambers can be independent or dependent to each other. In the independent pressure chambers, each chamber can operate without pressure in adjacent chamber. However, in case of dependent units, both the chambers need to pressurize simultaneously so that the common element is subjected to the differential pressure.

The design and fabrication of common element have many complexities. If the vessel is in sour service or the operating fluid is corrosive in nature then the vessel inside as well as both sides of intermediate dished head require high alloy metal lining. In such case the design of weld joint for intermediate dished head to shell require additional sequence of operation; these will be discussed in detail in the subsequent section of this paper. The availability of both side clad plates is also very limited and only few steel mills offer this type of plates. The dished head can also be made with single side clad plate with weld overlay on

the other side or both side overlay, if proper care is taken to control the distortion.

The thickness of common element of a combination unit, which operates as an independent chamber, is generally very high as this need to be designed with pressure and temperature on convex side of dished head equal to the pressure inside one of the chamber. Due to high thickness it becomes difficult to form the dished head.

On the other hand, as one chamber is directly placed above the other, omits the requirement of additional structure for top chamber, and in turn reduces the cost of material.

As an alternative to combination unit, two chambers with independent dish-end and an intermediate skirt support can also be used. Refer figure (b).

Design

Pressure chambers of combination units can be designed to operate independently and in this case each element, including the common elements, shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation.

It is also permitted to design each common element for a differential pressure less than the maximum of the design pressures of its adjacent chambers or a mean metal temperature less than the maximum of

the design temperatures of its adjacent chambers or a combination of both.

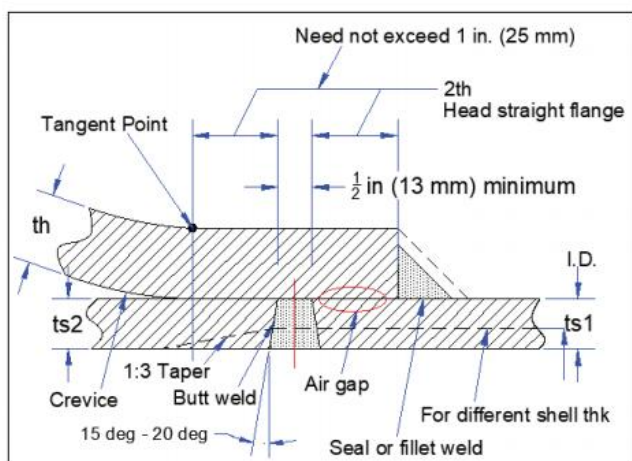
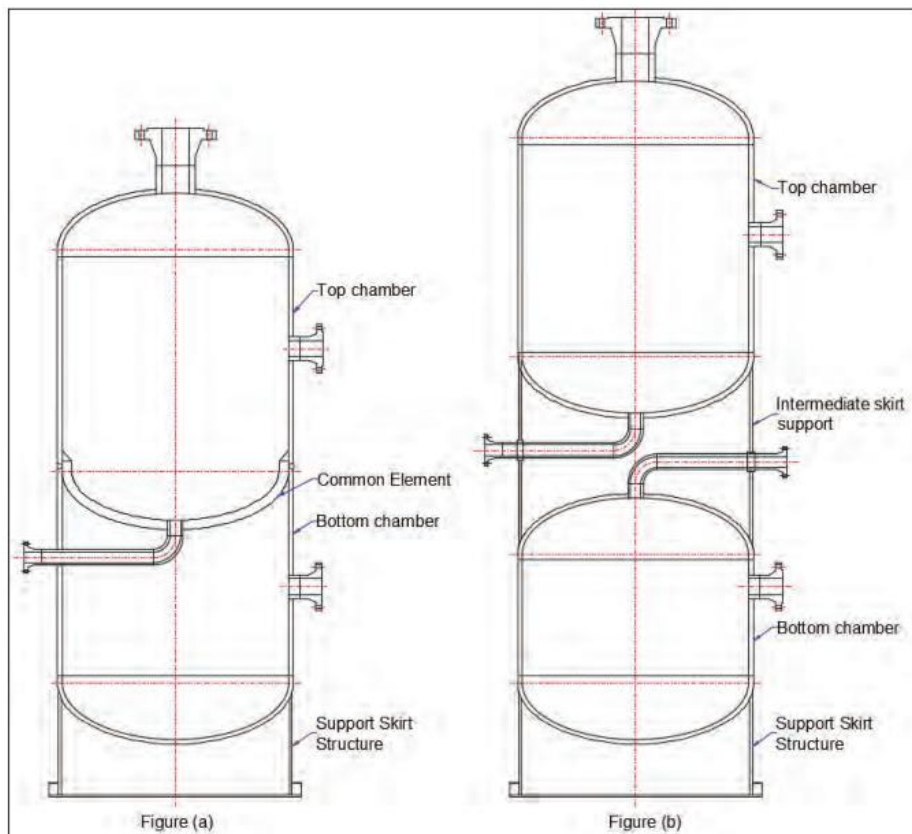
Joint configuration of the type shown in Figure (c) is generally used for all types of vessels. However, the outside diameter of the head straight flange shall be a close fit inside the overlapping ends of the adjacent length of cylinder.

The shell circumferential joint shall be considered as backing strip joint with efficiency as per the extent of radiography considered.

For the strength calculation of this joint the butt weld and fillet weld shall be able to take shear based on 1.5 times the maximum differential pressure that can exist. The allowable stress value for the butt weld shall be 70 percent of the stress value for the vessel material and that of the fillet it shall be taken as 55 percent. The area of the butt weld in shear is the width at the root multiplied by the length of weld. The area of the fillet weld is the minimum leg dimension multiplied by the length of weld. The fillet weld may be omitted based on the process conditions.

Fabrication

In the combination units the most difficult joint is the combination of shell and intermediate dished head. The shape and size of dished head shall be such that it shall form a close fit with the adjacent shells. There will be a small air gap on top



Where,
 th : Head thickness
 $ts1, ts2$: Adjacent shell thickness
 $I.D.$: Inside diameter

Figure (c)

side of the butt joint, refer figure (c), proper arrangement shall be made for venting of this air due to heating during welding or operation.

Below sequence of fabrication provides one of the solutions to the issues discussed above.

- 1) Clad stripping of bottom side of top shell adjacent to the joint to the suitable length. Refer figure (d) step 1.
- 2) Carbon steel or low alloy steel buttering of stripped area, leaving a small gap from clad portion, Refer figure (d) step 2.
- 3) Drill vent holes up to shell buttering. Refer figure (d) step 3.
- 4) Clad stripping of top side of bottom shell adjacent to the joint to the suitable length. Refer figure (d) step 4.
- 5) Carbon steel or low alloy steel buttering of stripped area, leaving a small gap from clad portion, refer figure (d) step 5.
- 6) Gap on bottom shell shall be filled with nickel alloy or higher alloy than cladding chemistry. Refer figure (d) step 6.
- 7) Clad stripping on both the sides of intermediate dished head to suitable length. Refer figure (d) step 7.

8) Carbon steel or Low alloy steel buttering of stripped area on outside of dished head, leaving a small gap from cladding. Refer figure (d) step 8.

9) Gap on step 8 shall be filled with nickel alloy or higher alloy than cladding chemistry. Refer figure (d) step 9.

10) Assemble top shell, bottom shell, and dished head ensuring proper fitment. Refer figure (d) step 10.

11) Carryout the circumferential weld with carbon steel or low alloy steel consumables based on chemistry of base material. Carryout the fillet welding from inside. Refer figure (d) step 11.

12) Clad restoration from inside with high alloy lining. Refer figure (d) step 12.

In step 2, 5, 8 and 11 the selection of carbon steel or low alloy steel will depend on the base material used for construction of vessel. Also, proper clad stripping on each step shall be ensured with CuSO_4 or HNO_3 tests. On completion of fabrication and testing of equipment, the vent hole shall be filled with hard grease to avoid any ingress of water or moisture during transportation or operation.

The lining on dished head straight flange outside surface is required to strip back, without which it will not be possible to make the shell butt joint with carbon steel or low alloy steel consumables as this will result in brittle welds.

Other possible weld configurations can be either the use of nickel based consumables for the shell butt joint keeping the lining on outside of dished head, or the solid stainless steel head instead of double side metal lined intermediate dished head. With stainless steel dished head the butt joint between top and bottom shell is to be made with stainless steel consumables. In both these arrangements at higher temperatures there are thermal expansion differences between carbon steel or low alloy on the one hand, and nickel based or stainless steel alloy on the other, which generates additional stresses on this joint and is not a very good solution.

Testing

Once the fabrication is complete and all the nondestructive tests are done, the vessel shall be subjected to hydro-test as per rules of applicable construction code. If the pressure chambers of combination units are designed to operate independently

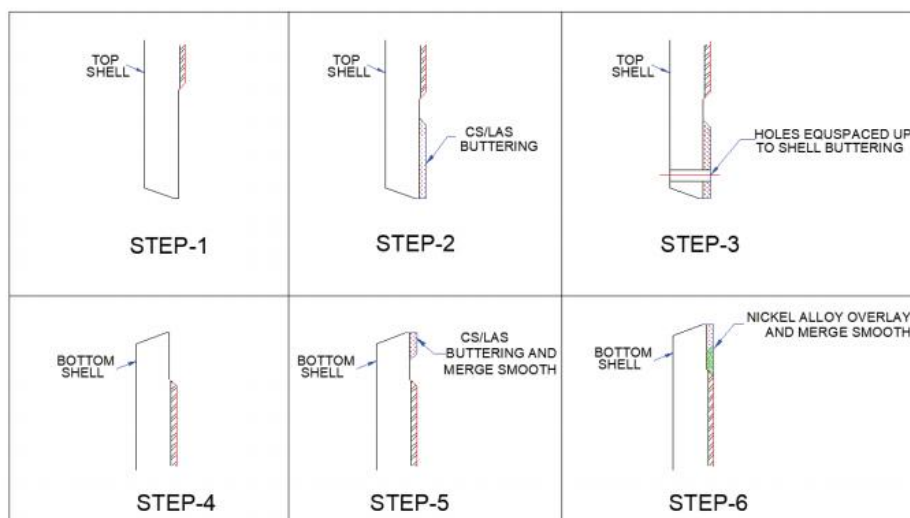


Figure (d)

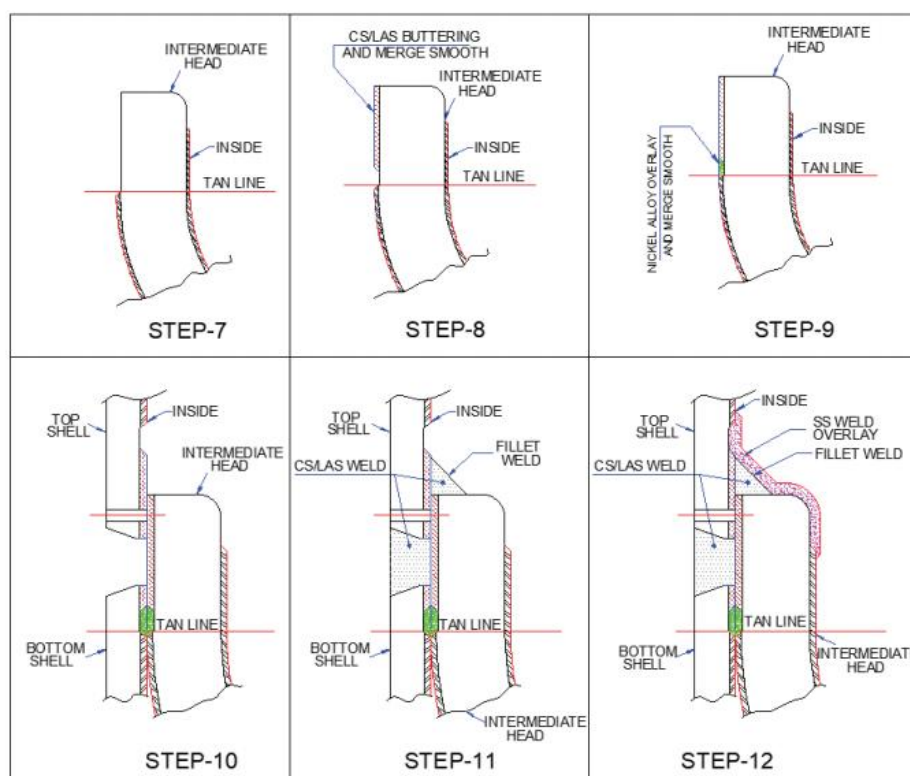


Figure (d)

then each chamber shall be hydrostatically tested as separate vessels, that is, each chamber shall be tested without pressure in the adjacent chamber.

When pressure chambers of combination units have their common elements designed for the maximum differential pressure the common elements shall be subjected to a hydrostatic test pressure based on the differential pressure to be marked on the unit. Care shall be taken that the common element is subjected to allowable differential pressure only.

Challenges of both sides metal lined common element

The thickness of common element of independent chamber combination units is generally very high; hence, the forming of dished head becomes very difficult. If the forming is done from a double side clad plate, then it adds further difficulties in forming as the lining may get damaged during forming.

Outside of straight flange of intermediate dished head and the inside of adjacent shells shall be formed in very close tolerance both

in diameter and shape to ensure proper fitment and in many cases it may require to machine all the mating surfaces.

A crevice is formed on the bottom side of this joint between outside of dished head and bottom shell, refer figure (c), where any vapor formed at the bottom chamber can accumulate and chances of crevice corrosion are there, which is unavoidable with this configuration.

The straight flange of intermediate dished head works as permanent backing strip for the adjacent shells, hence difficult to ensure proper nondestructive examination and repair of flaws in welding during fabrication, if any.

Conclusion

The use of common element, in case of lined vessels, shall be evaluated from process perspective, economy and ease of fabrication against the option of using an intermediate skirt. If a common element is used, the thickness of intermediate dished head increases; on the other hand, if an intermediate skirt is used, then one additional head and skirt will be required and this will reduce the complexities of fabrication to a large extent.

Use of stainless steel common elements is also not a feasible solution due to the differential thermal expansion of material at higher operating temperatures.

If a lined vessel with common element is the selected option then a well-planned fabrication sequence can be useful while manufacturing. This paper presents one of the possible sequences, which can be adopted by manufacturer.

References.

ASME Boiler and Pressure Vessel Code, Section VIII Div 1 and Div 2. ■

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